

Hydrologic Forecasting With Statistical Models

Angus Goodbody

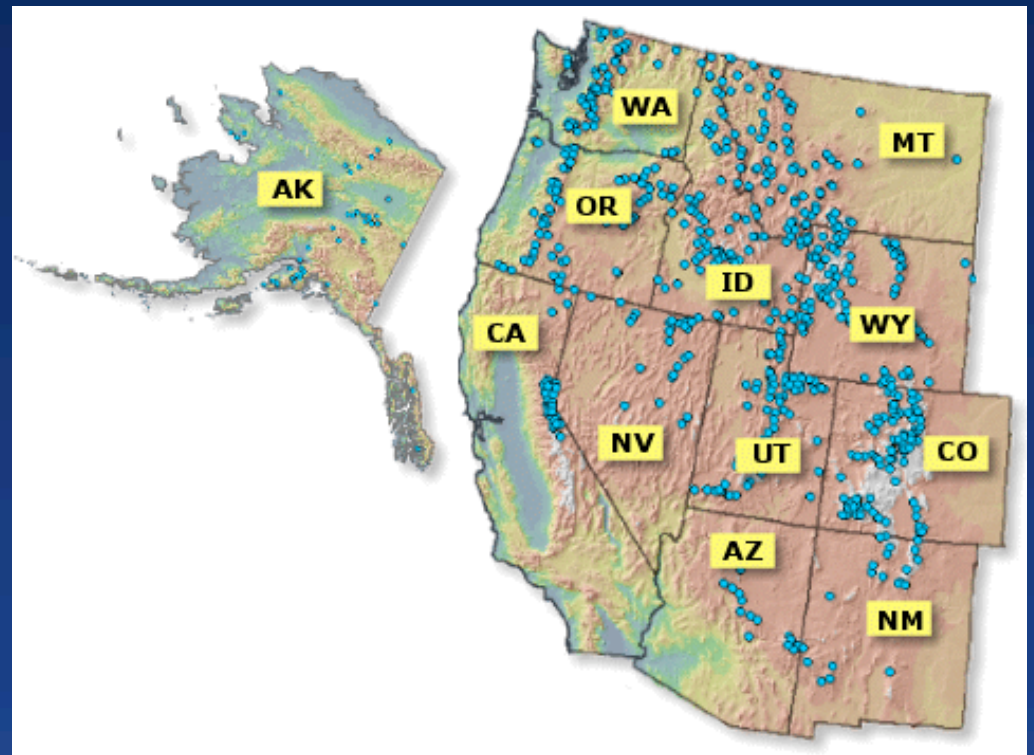
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Presented at
American Meteorological Society Annual Meeting
Seattle, Washington
January 2011

Snow Survey and Water Supply Forecasting Program

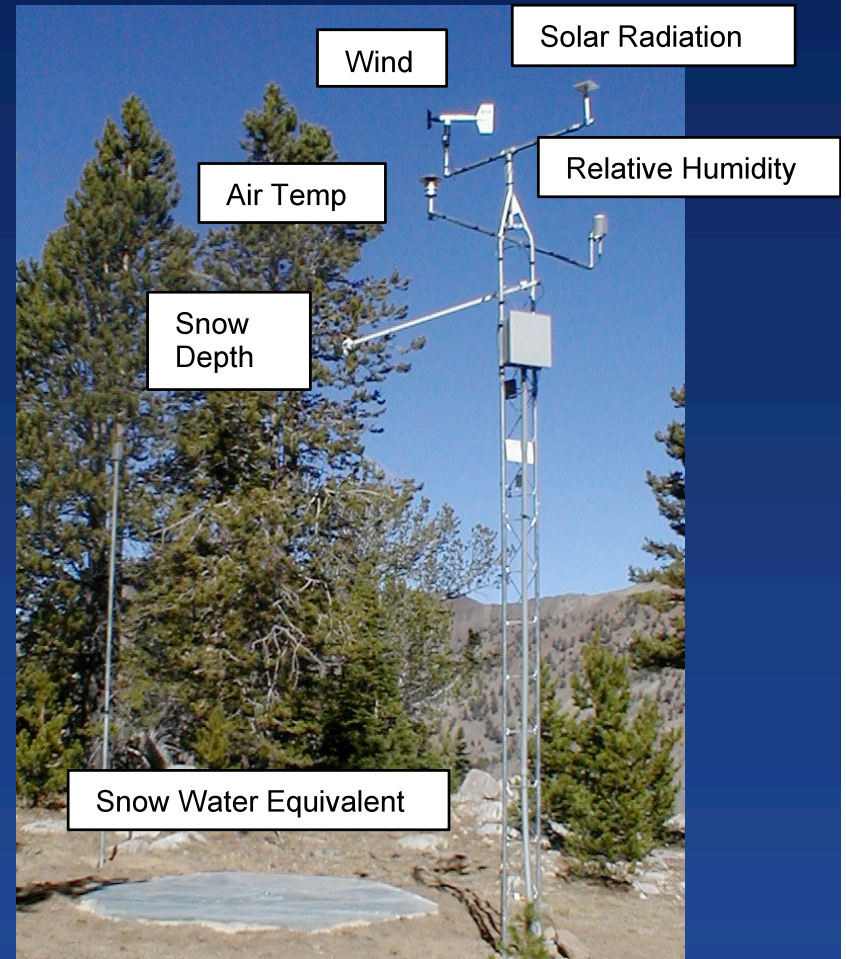
- Data collection
- Water supply forecasts
- Climate services



SNOTEL Network

Currently over 800 sites
in 13 western states

<http://www.wcc.nrcs.usda.gov/snow>



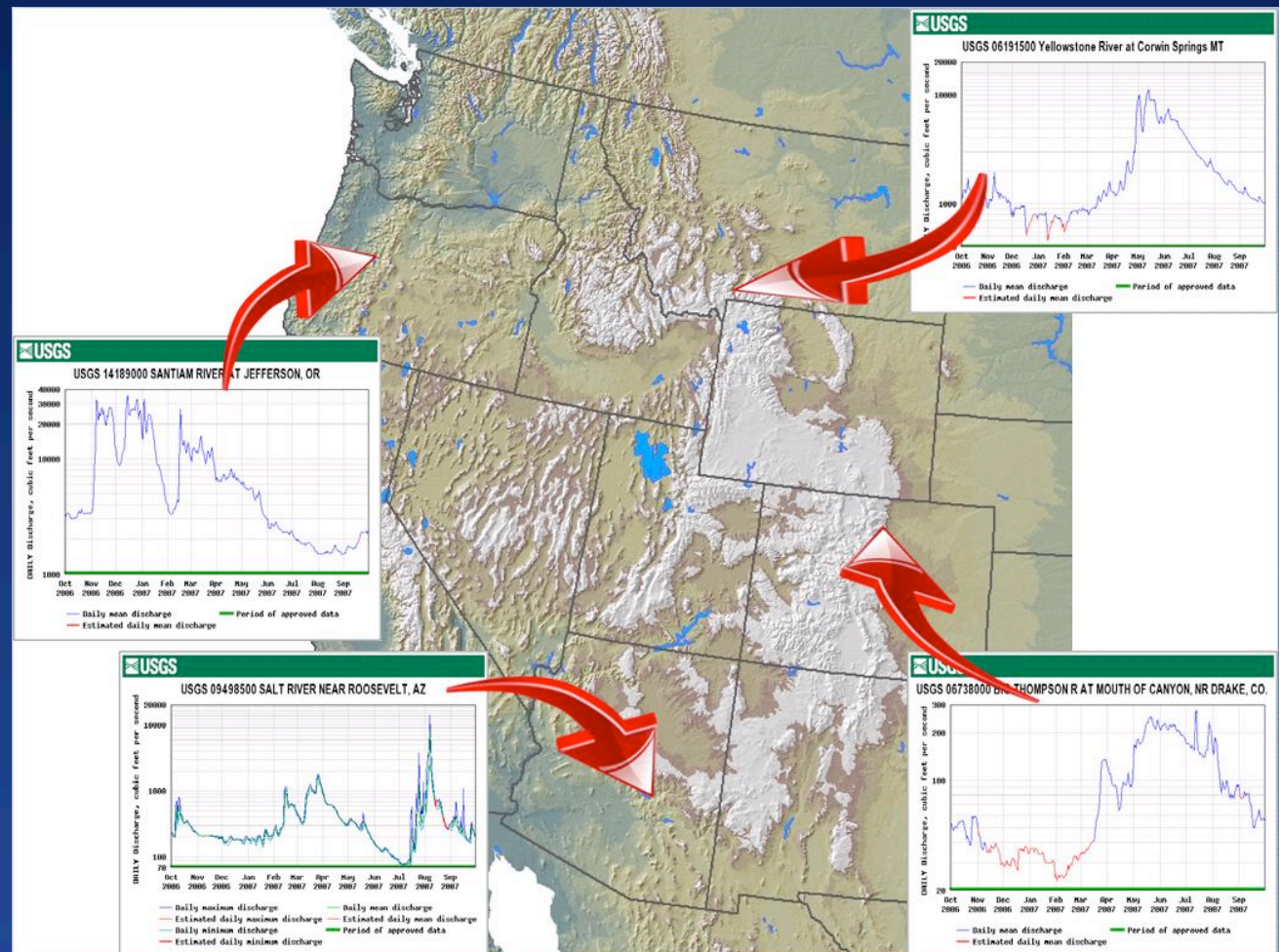
Water Supply Forecasting

- Seasonal streamflow volume
- Published January through June
- Cooperative effort with National Weather Service
- Over 700 forecast points in western US



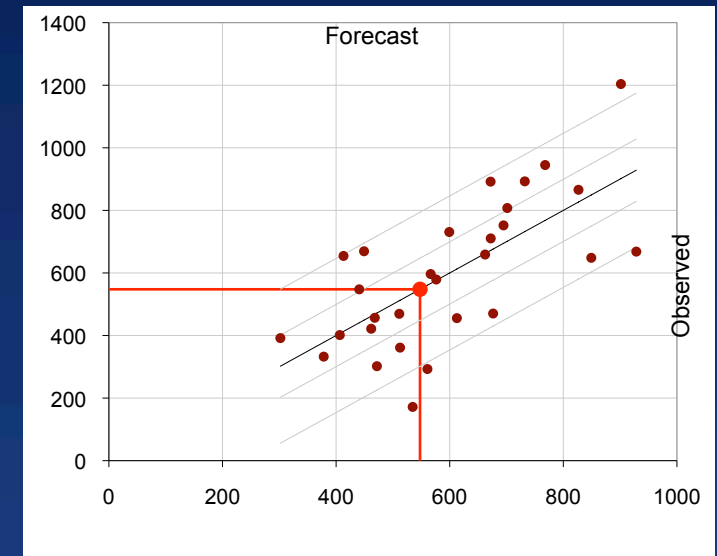
Hydroclimatic Regime Issues

- Yellowstone: snowmelt dominant
- Big Thompson: snowmelt + spring precip
- Salt: minor snowmelt + monsoon
- Santiam: winter rain dominant



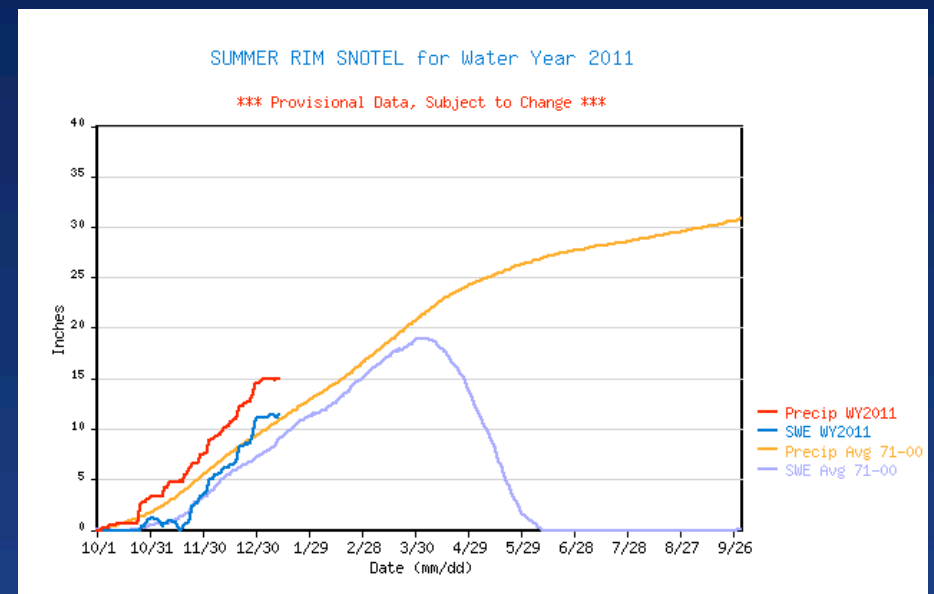
Statistical Modeling: Techniques

- Regression models: Principal components or Z-score
- Optimization: Time period and variable search
- Jackknife (cross-validation) test
- Linear or transformed target variable



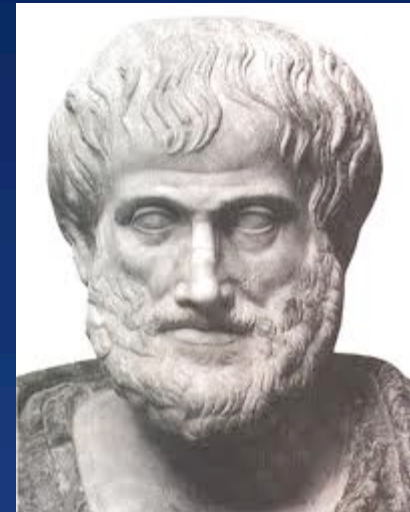
Statistical Modeling: Standard Data

- SNOTEL: SWE, precipitation, temperature
- Snowcourse: SWE
- NWS cooperative network: precipitation
- USGS: streamflow
- Climate teleconnection indices



Model Building Philosophy

- Robust models
- Month-to-month consistency
- Physically meaningful and explainable
- Statistically valid
- Operationally useful



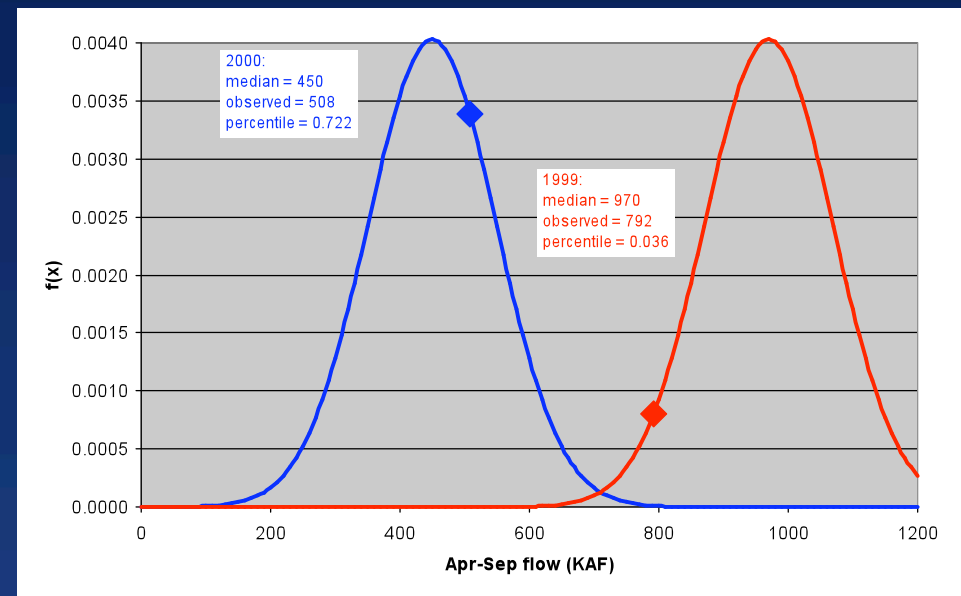
United States Department of Agriculture
Natural Resources Conservation Service



SPRAGUE R.	Jan	Feb	Mar	Apr	May	Jun
<u>SWE:</u>						
Silver Creek	Jan	Feb	Mar	Apr	Apr	---
Strawberry	Jan	Feb	Mar	Apr	---	---
Summer Rim	Jan	Feb	Mar	Apr	May	Jun
Taylor Butte	Jan	Feb	Mar	Apr	---	---
<u>PRECIPITATION:</u>						
Quartz Mountain	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Silver Creek	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Strawberry	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Summer Rim	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Taylor Butte	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
<u>STREAMFLOW:</u>						
Sprague R. / Chiloquin	Nov-Dec	Nov-Dec	Nov-Dec	Mar	Apr	May
<u>CLIMATE INDEX:</u>						
Trans-Niño Index	Sep-Nov	Oct-Dec	Oct-Jan	Oct-Jan	Oct-Jan	Oct-Jan
<u>STATS:</u> JR, JSE	0.68, 85.2	0.83, 65.0	0.88, 54.5	0.95, 37.3	0.91, 34.6	0.91, 16.3
<u>STATS:</u> N, NPC	28, 1	28, 1	28, 1	28, 1	28, 2	28, 2

Forecast Uncertainty

- Usual regression assumptions of homoscedasticity and normal distribution of errors
- Forecast is interpreted as a conditional probability distribution
- NRCS publishes five values at different exceedance levels (90, 70, 50, 30, 10%)



Forecast Uncertainty

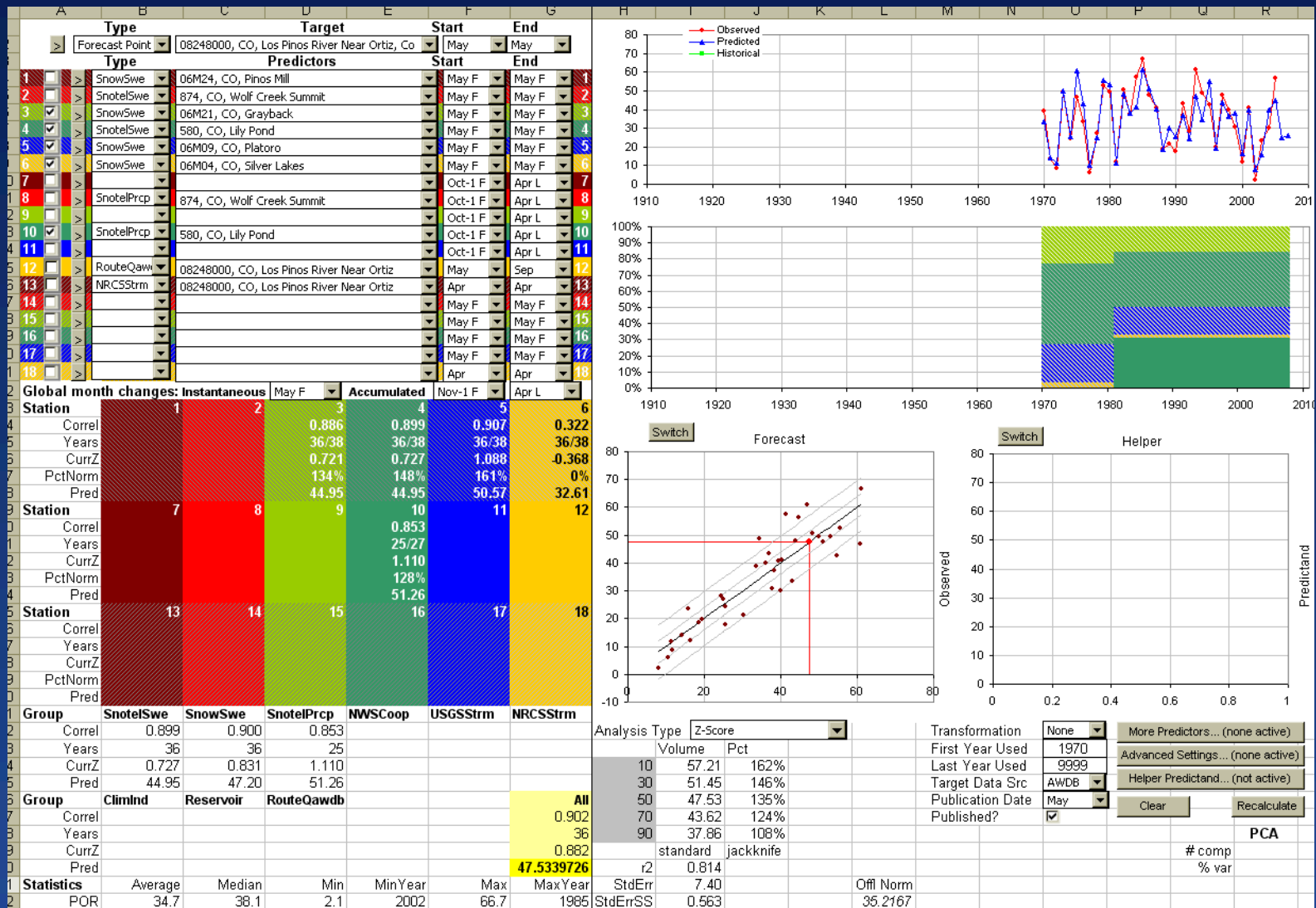
UPPER JOHN DAY BASIN							
Streamflow Forecasts - January 1, 2011							
	<=== Drier === Future Conditions === Wetter ===>						
Forecast Pt	Chance of Exceeding *						
Forecast	90%	70%	50%	30%	10%		30 Yr Avg
Period	(1000AF)	(1000AF)	(1000AF) (% AVG.)	(1000AF)	(1000AF)		(1000AF)
MF John Day R at Ritter							
MAR-JUL	136	173	199	125	225	260	159
APR-SEP	106	138	160	125	182	215	128
NF John Day R at Monument							
MAR-JUL	695	870	990	125	1110	1280	790
APR-SEP	530	675	770	125	865	1010	615

VIPER: Visual Interactive Prediction and Estimation Routines

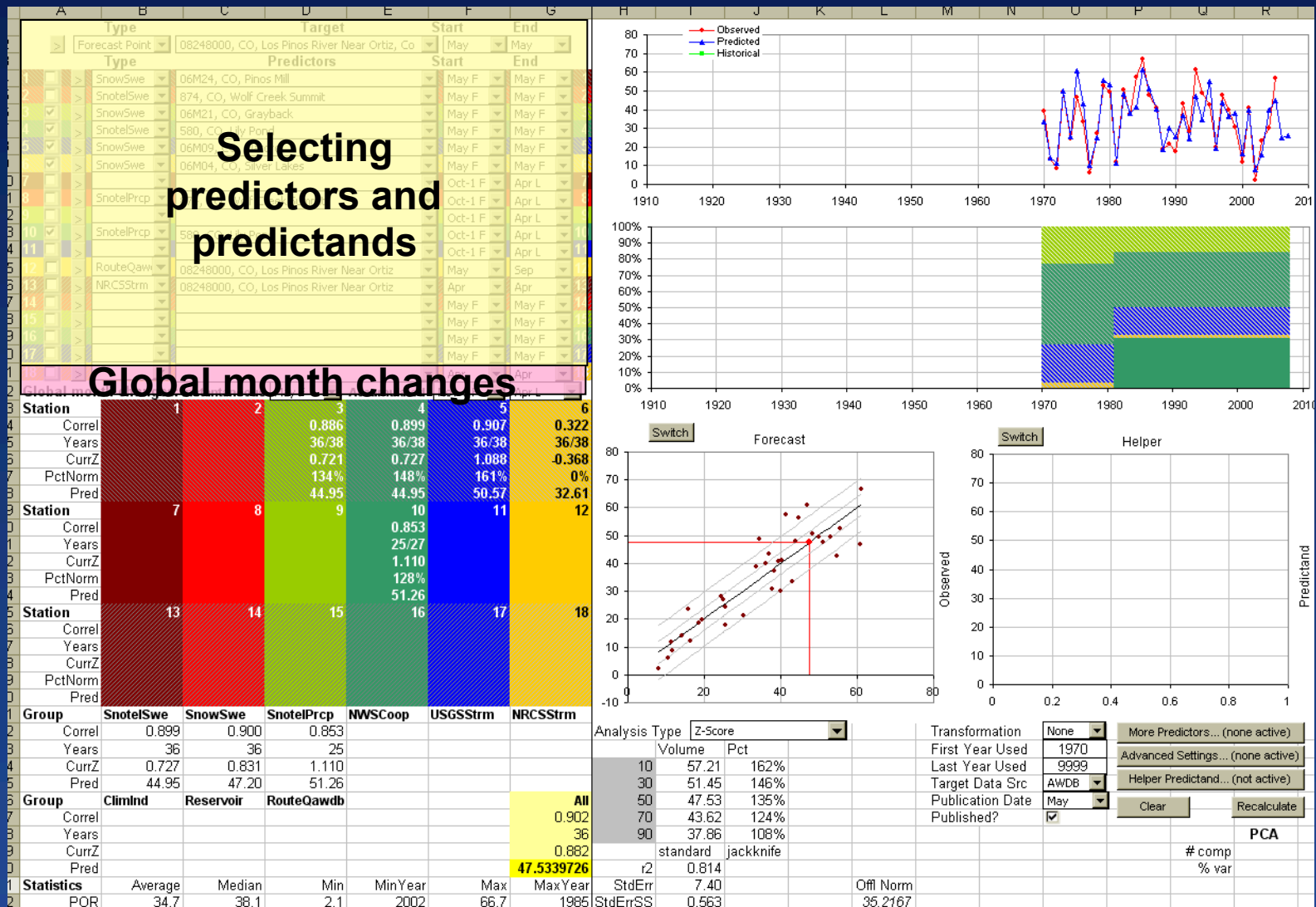
VIPER is our software environment containing all of the statistical algorithms that we employ plus equation management and operational forecasting utilities.

VIPER is an Excel spreadsheet application with macros and with live web-based data retrieval from the NRCS-NWCC and USGS databases.

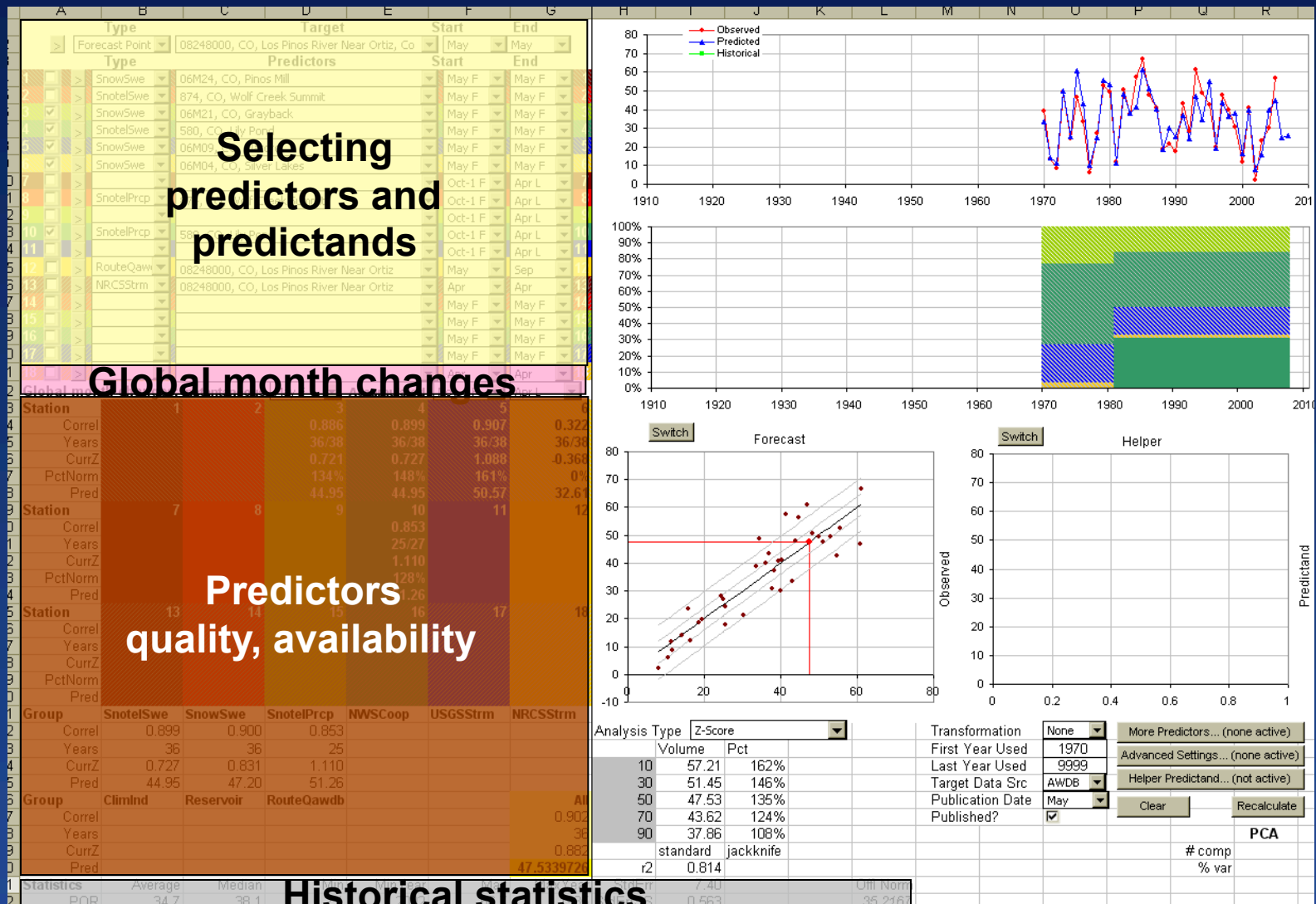
VIPER Main Interface



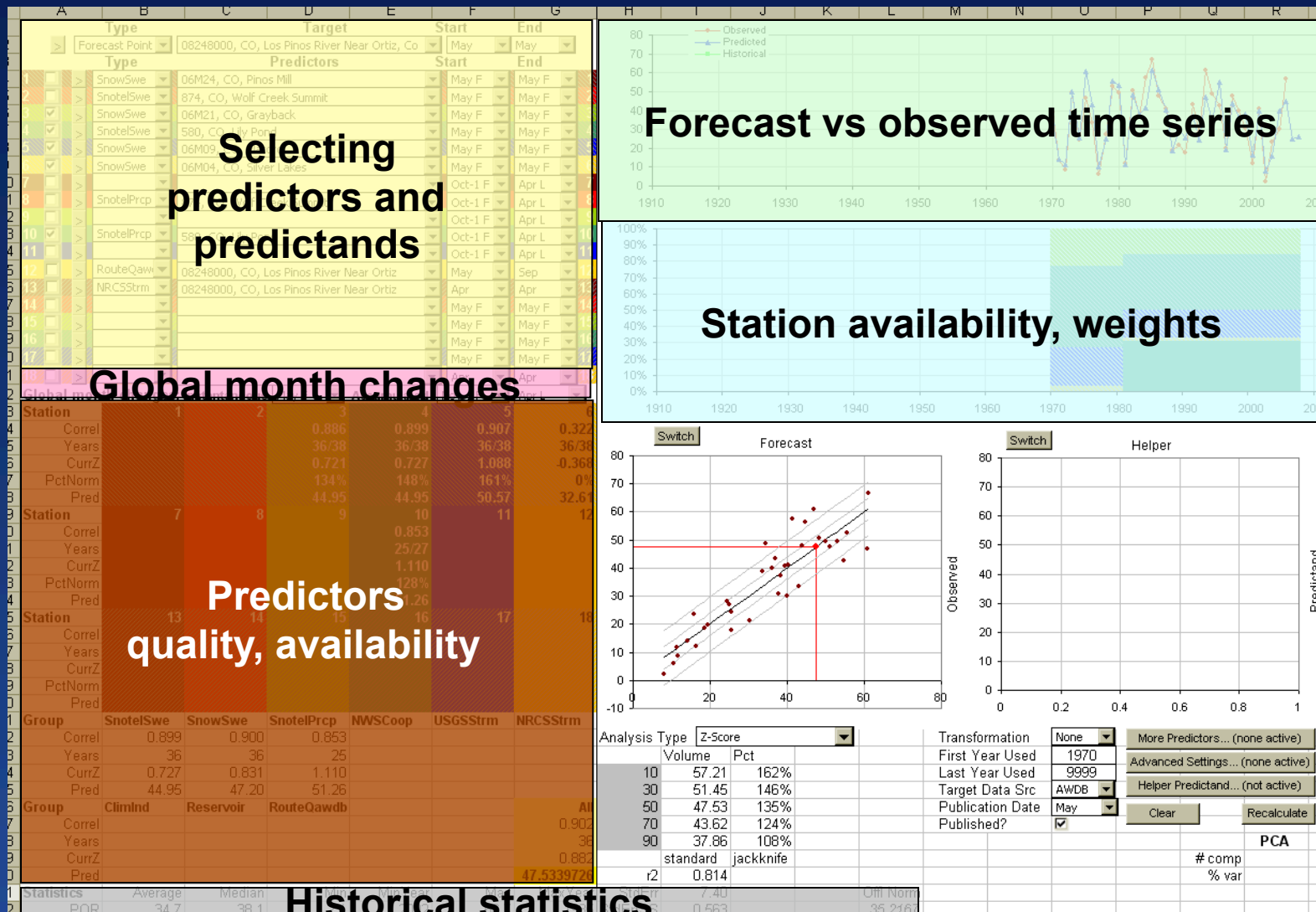
VIPER Main Interface



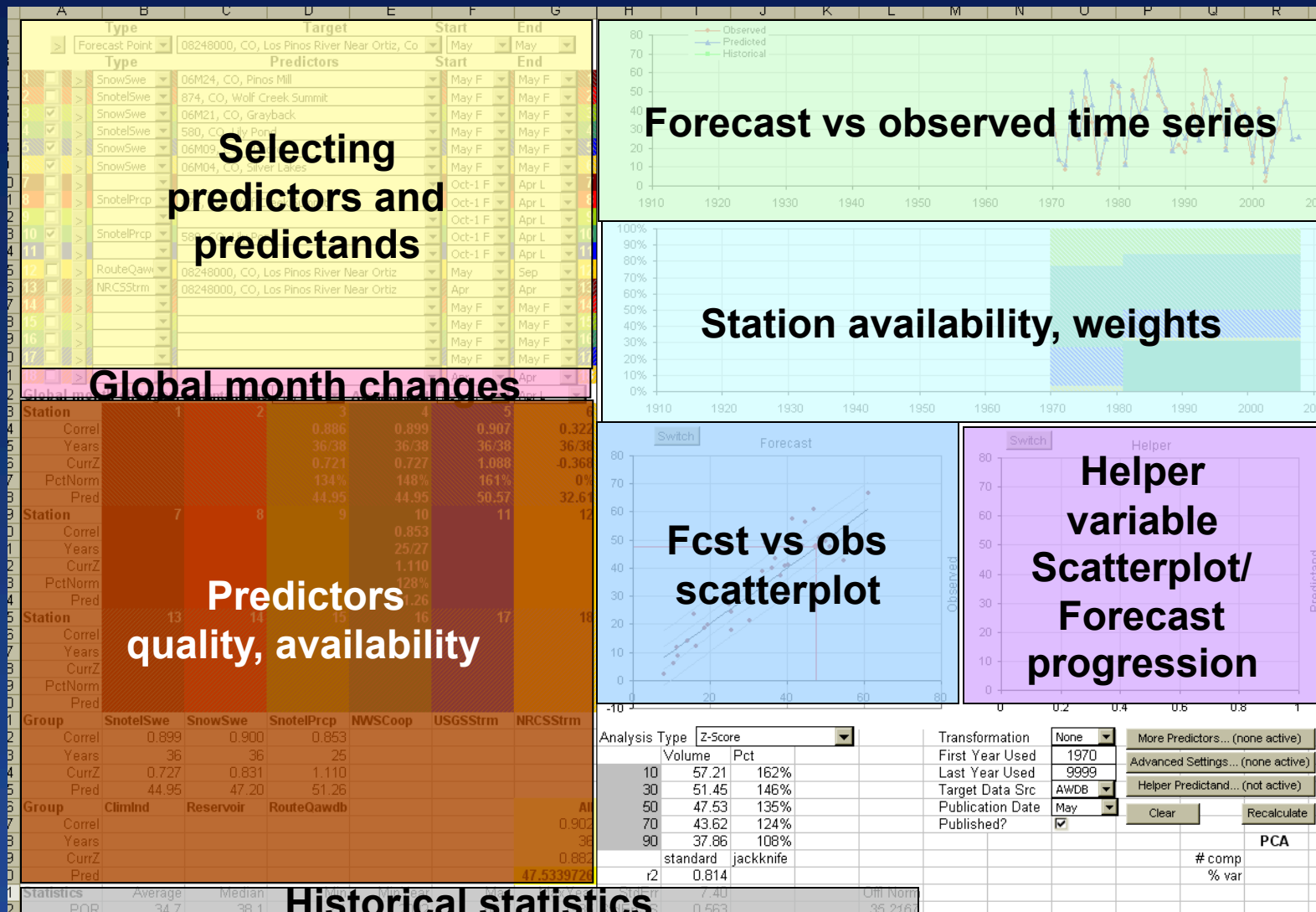
VIPER Main Interface



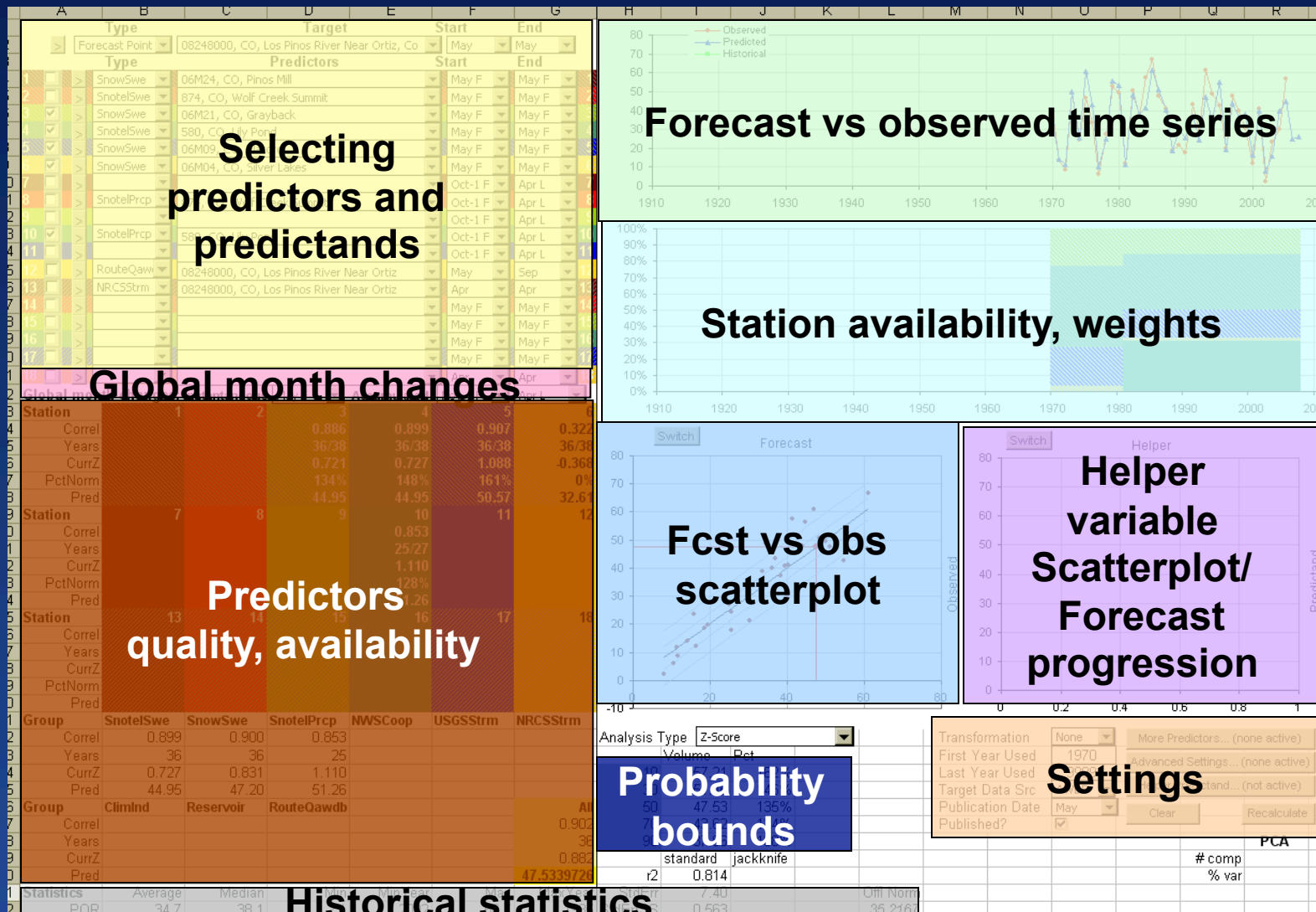
VIPER Main Interface



VIPER Main Interface

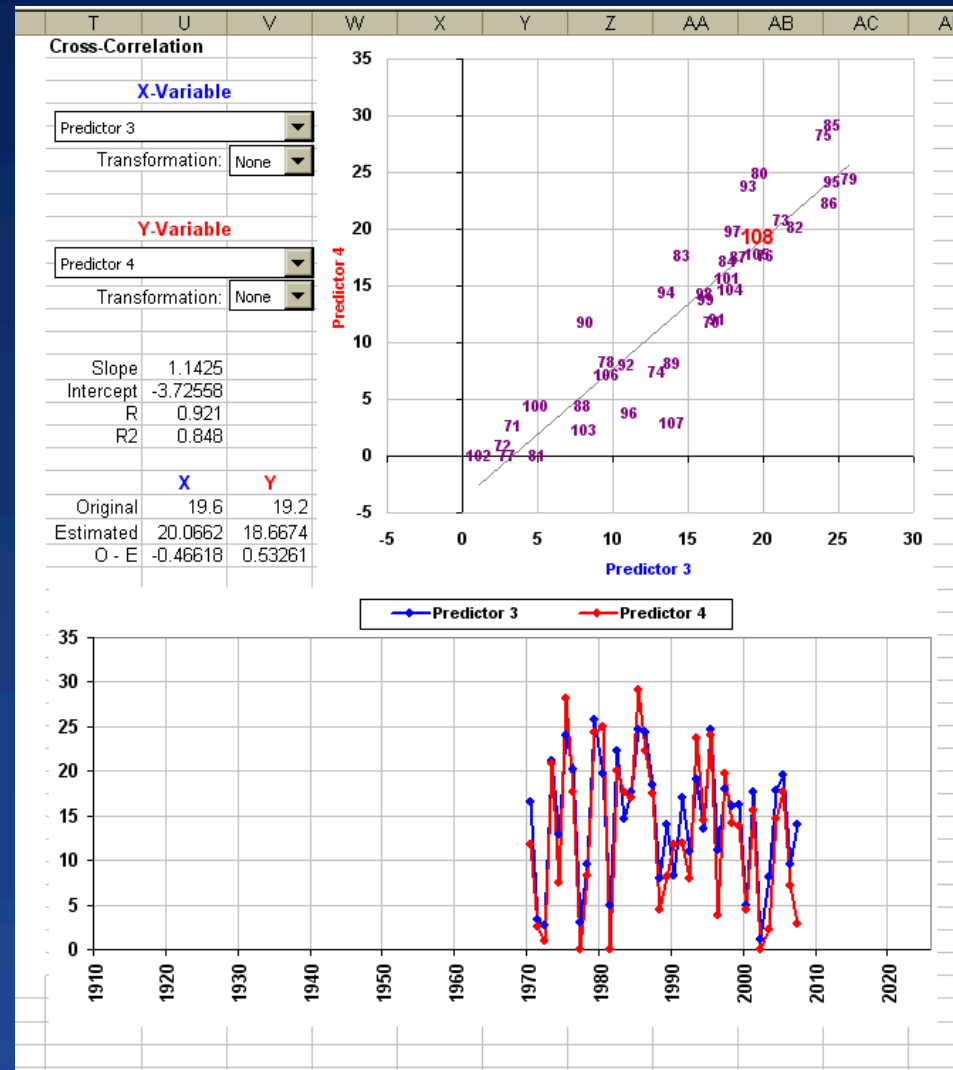


VIPER Main Interface



VIPER Main Interface

And, off to the right, is a scatterplot and time series plot.



VIPER Main Interface

Selecting the target and predictors -- closeup:

	A	B	C	D	E	F	G	H
1		Type		Target			Start	End
2	>	Forecast Point ▾		10234500, UT, Beaver R Nr Beaver, Ut ▾			Apr ▾	Jul ▾
3		Type		Predictors			Start	End
4	1	✓	>	SnotelSwe ▾	621, UT, Merchant Valley ▾		Apr F ▾	Apr F ▾
5	2	✓	>	SnotelSwe ▾	339, UT, Big Flat ▾		Apr F ▾	Apr F ▾
6	3	✓	>	SnotelSwe ▾	557, UT, Kimberly Mine ▾		Apr F ▾	Apr F ▾
7	4	✓	>	SnotelPrcp ▾	621, UT, Merchant Valley ▾		Oct-1 F ▾	Mar L ▾
8	5	✓	>	SnotelPrcp ▾	339, UT, Big Flat ▾		Oct-1 F ▾	Mar L ▾
9	6	✓	>	SnotelPrcp ▾	557, UT, Kimberly Mine ▾		Oct-1 F ▾	Mar L ▾
10	7		>				Jan-1 ▾	Jan-1 ▾
11	8		>				Jan-1 ▾	Jan-1 ▾
12	9		>				Jan-1 ▾	Jan-1 ▾
13	10		>				Jan-1 ▾	Jan-1 ▾

VIPER Station Optimization

VIPER REGRESSION COMBINATION OPTIMIZATION SUMMARY OUTPUT

Number of combinations evaluated = 727
Created on 1/12/2011 10:43:11 AM by dgaren

Transformation type: None
Analysis type: Principal Components

VARIABLES:

Y1	14046000, APR-SEP, SRVO, USGS, OR, USGS, N. F. John Day At Monument
X1	304, JAN, WTEQ, SNTL, OR, AWDB, Arbuckle Mtn
X2	361, JAN, WTEQ, SNTL, OR, AWDB, Bourne
X4	494, JAN, WTEQ, SNTL, OR, AWDB, Gold Center
X5	605, JAN, WTEQ, SNTL, OR, AWDB, Lucky Strike
X6	608, JAN, WTEQ, SNTL, OR, AWDB, Madison Butte
X7	821, JAN, WTEQ, SNTL, OR, AWDB, Tipton
X9	304, OCT-DEC, PRCP, SNTL, OR, AWDB, Arbuckle Mtn
X10	361, OCT-DEC, PRCP, SNTL, OR, AWDB, Bourne
X12	494, OCT-DEC, PRCP, SNTL, OR, AWDB, Gold Center
X13	605, OCT-DEC, PRCP, SNTL, OR, AWDB, Lucky Strike
X14	608, OCT-DEC, PRCP, SNTL, OR, AWDB, Madison Butte
X15	821, OCT-DEC, PRCP, SNTL, OR, AWDB, Tipton
X17	TNI, JUL-NOV, OI, CLMIND, NA, AWDB, Tni Climate Index

VIPER Station Optimization

EQUATION SUMMARY:

RANK	VARIABLES																														JACKKNIFE	JACK. NUM.		
																															STANDARD	CORR.	OBS.	NUM.
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	ERROR	COEF.	USED	PC'S
1						X							X																		156.567	0.753	29	1
2				X	X			X					X																		160.246	0.751	29	2
3				X	X								X	X			X														161.365	0.747	29	2
4						X		X					X	X																	161.641	0.746	29	2
5				X	X			X					X	X																	161.795	0.745	29	2
6				X	X								X	X																	162.049	0.744	29	2
7				X	X			X					X		X		X														162.053	0.745	29	2
8						X							X	X																	162.194	0.732	29	1
9						X			X				X																		162.247	0.731	29	1
10				X	X								X																		162.415	0.731	29	1
11						X							X		X		X														162.505	0.730	29	1
12						X	X						X	X																	162.570	0.731	29	1
13						X		X					X		X		X														162.664	0.742	29	2
14		X				X							X																		162.678	0.730	29	1
15				X	X				X				X																		163.013	0.741	29	2
16				X	X			X					X	X		X		X													163.023	0.741	29	2
17						X							X	X		X		X													163.123	0.741	29	2
18				X	X								X	X		X		X													163.148	0.740	29	2
19				X	X			X	X				X																		163.207	0.740	29	2
20		X		X	X			X					X																		163.364	0.740	29	2

Examples of Equation Development

Colorado River

John Day River

Remainder of presentation is a live demo ...

United States Department of Agriculture
Natural Resources Conservation Service



NF JOHN DAY R.	Jan	Feb	Mar	Apr	May	Jun
<u>SWE:</u>						
Arbuckle Mountain	Jan	Feb	Mar	Apr	May	May
Bourne	Jan	Feb	Mar	Apr	May	May
Gold Center	Jan	Feb	Mar	Apr	---	---
Lucky Strike	Jan	Feb	Mar	Apr	---	---
Madison Butte	Jan	Feb	Mar	Apr	---	---
Tipton	Jan	Feb	Mar	Apr	May	May
<u>PRECIPITATION:</u>						
Arbuckle Mountain	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Bourne	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Gold Center	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Lucky Strike	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Madison Butte	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
Tipton	Oct-Dec	Oct-Jan	Oct-Feb	Oct-Mar	Oct-Apr	Oct-May
<u>STREAMFLOW:</u>						
NF John Day / Monument	---	---	---	Mar	Mar-Apr	May
<u>CLIMATE INDEX:</u>						
Trans-Niño Index	Jul-Nov	Jul-Dec	Jul-Dec	Jul-Dec	Jul-Dec	Jul-Dec
<u>STATS:</u> JR, JSE	0.64, 183.0	0.73, 160.3	0.71, 165.8	0.82, 135.3	0.79, 111.7	0.83, 48.1
<u>STATS:</u> N, NPC	26, 1	26, 1	26, 1	26, 1	26, 2	26, 2